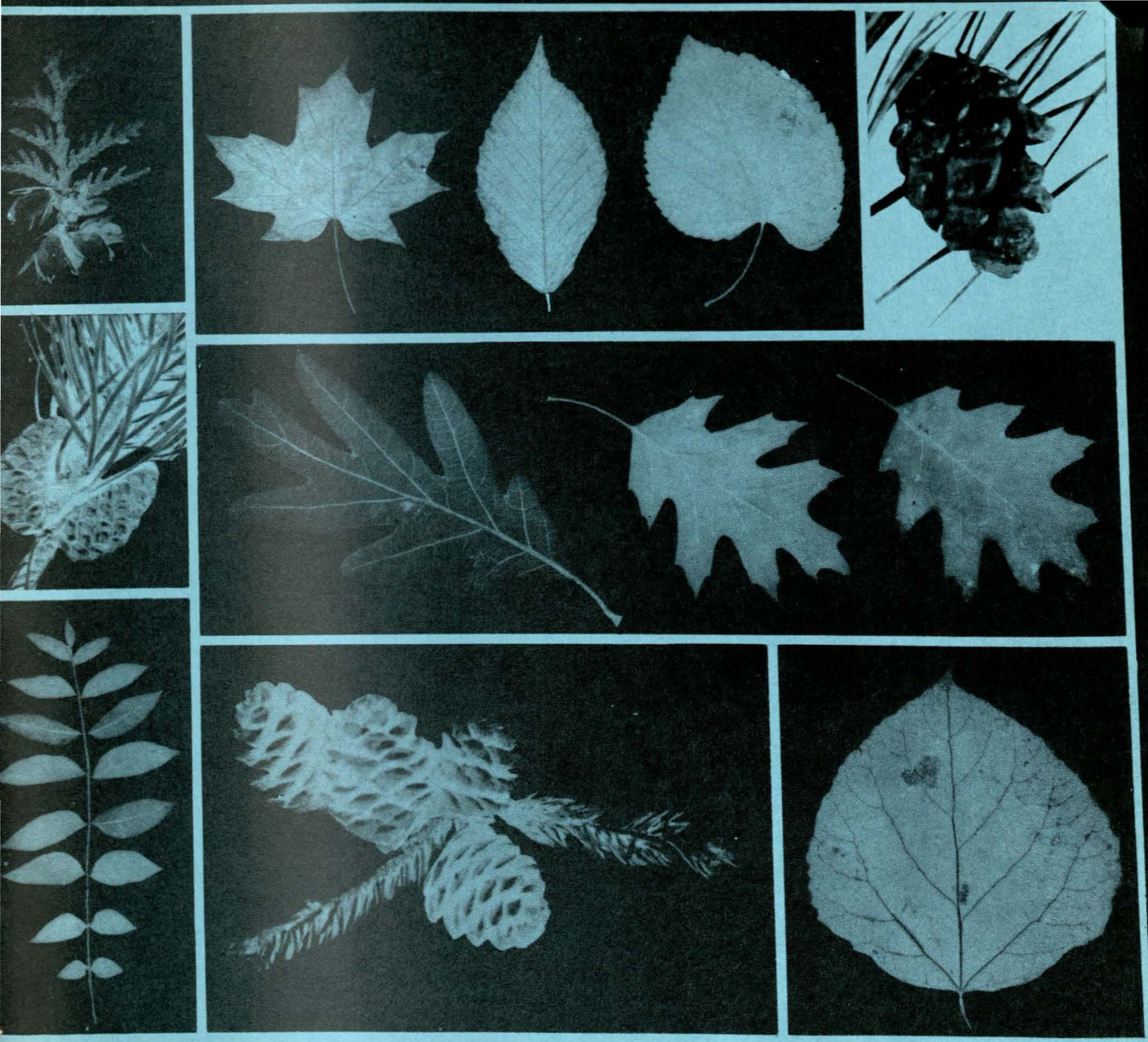

manager's handbook for

RED PINE IN THE NORTH CENTRAL STATES

GENERAL TECHNICAL REPORT NC-33

NORTH CENTRAL FOREST EXPERIMENT STATION FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

Other Manager's Handbooks are:

Jack pine – GTR-NC-32
Black spruce – GTR-NC-34
Northern white-cedar – GTR-NC-35
Aspen – GTR-NC-36
Oaks – GTR-NC-37
Black walnut – GTR-NC-38
Northern hardwoods – GTR-NC-39

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FOREWORD

This is one of a series of manager's handbooks for important forest types in the north central States. The purpose of this series is to present the resource manager with the latest and best information available on handling these types. Timber production is dealt with more than other forest values because it is usually a major management objective and more is generally known about it. However, ways to modify management practices to maintain or enhance other values are included where sound information is available.

The author has, in certain instances, drawn freely on unpublished information provided by scientists and managers outside his specialties. He is also grateful to the several technical reviewers in the region who made many helpful comments.

The handbooks have a similar format, highlighted by a "Key to Recommendations". Here the manager can find in logical sequence the management practices recommended for various stand conditions. These practices are based on research, experience, and a general silvical knowledge of the predominant tree species.

All stand conditions, of course, cannot be included in the handbook. Therefore, the manager must use technical skill and sound judgment in selecting the appropriate practice to achieve the desired objectives. The manager should also apply new research findings as they become available so that the culture of these important forest types can be continually improved.

RED PINE
IN THE NORTH-CENTRAL STATES

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SILVICAL HIGHLIGHTS

A century ago red pine[1] made up about a third of the 22 million acres of pine forests in Minnesota, Wisconsin, and Michigan; today it covers only a little more than 1 million acres – mostly acreage planted since 1930.

Red pine on the drier sites grows in pure stands and in mixtures with jack pine, aspen, paper birch, and scrub oaks; on the more moist sites with white pine, red maple, red oak, balsam fir, and white spruce. Red pine grows best on well drained sandy to loamy soils but the tree is most common on sandy soils where site index may range from 45 to 75 feet at 50 years of age.

Red pine is shade intolerant and long-lived; some stands reach 200 years of age, and some individual trees about 400 years, but commercial rotation ages are generally between 60 and 120 years. Red pine often succeeds its less tolerant and shorter-lived associates such as jack pine, paper birch, and the aspens; in turn it is succeeded by its more shade tolerant associates that regenerate in the understory more easily. Wildfires occasionally disrupt ecological succession and a few thick-barked, old-growth trees usually survive to establish a pure seedling stand or a mixed stand of red pine and other intolerant species.

Seed production in mature red pine is irregular; heavy crops occur at intervals of 10 years or more. Red pine phenotypes are very homogenous showing little variation over the entire range. In some localities red pine suffers losses from diseases, insects, mammals, and weather, but it generally has fewer natural enemies than its associated species.

MANAGEMENT OBJECTIVES AND NEEDS

Management objectives considered in this handbook are to control the establishment, composition, and growth of red pine forest stands so that intermediate thinnings will provide useful products such as pulpwood, posts, poles, cabin logs, piling, and small sawtimber, and the final harvest will yield high quality sawtimber and veneer. The management of red pine forest stands throughout their rotation for other uses such as recreation, wildlife habitat, and watersheds is also covered and suggestions are given for increasing these benefits.

Although it is possible to grow red pine in either even-aged or uneven-aged stands, even-aged silvicultural systems give better results because red pine grows best in full sunlight.

Red pine seed crops are too variable to depend on for natural regeneration, so seed must be collected during good seed years for direct seeding, growing container seedlings, or growing bare root planting stock. Seedling establishment requires site preparation on areas where slash or vegetation, particularly sod or shrubs, covers the seedbed or planting site. Red pine seedlings often require tending for several years after they are established to release them from regrowth of competing vegetation and protect them from damage by fire, insects, and disease.

Periodic thinning of young stands is recommended to put the growth on the best trees available, maintain

[1] *For scientific names of plants and animals, see Appendix, p. 20.*

uniform growth rates, remove diseased and injured trees, shorten rotations, and increase the yield. Considerable flexibility in rotation age, with only slightly lower yields, provides opportunities to adjust age classes, extend rotations on areas where big trees are important, or harvest stands early to meet changing needs.

To help meet projected needs for softwood sawtimber the red pine type should be restored as soon as possible on several million acres of the more than 10 million acres in the Lake States that converted to other cover types after the original pine logging. Improved systems for site preparation, seedling establishment, and control of species composition are needed so that conversion can be done more efficiently and can be more effective for other uses such as recreation and wildlife habitat during the period of stand establishment.

KEY TO RECOMMENDATIONS

The following key is based primarily on the technical aspects of forest management – silviculture, protection, and regulation. The administrative aspects – economic, legal, and social – have only limited influence in the key so the user is cautioned to evaluate these aspects carefully when applying the technical recommendations.

The key recommends management practices for some of the common site and stand conditions encountered in the red pine type or on potential red pine sites. Use of the key in conjunction with a stand examination will lead to one or more general recommendations. Each recommendation refers to the appropriate section under "Management Considerations" where optional silvicultural tools and methods are discussed.

To use the key, start with the first pair of numbered statements. Choose the statement that best describes the situation and find either a number only, a recommendation and a number, or a recommendation only. If a number is given, find the pair of statements with that number and continue the process until a recommendation only is reached. All recommendations encountered in going through the key should be considered in your prescription.

1. **Red pine stand** 2
   See "Stand Conditions–Type", p. 3
1. **Other stands or the area is nonstocked** 14
   2. **Even-aged stand** 3
      See "Stand Conditions–Age", p. 4
   2. **Uneven-aged stand** 12
3. **Stand has minimum or higher stocking** 4
   See "Stand Density", p. 4 and fig. 1, Appendix
3. **Stand is below minimum stocking** 14
   4. **Stand is not mature** 5
      See "Rotation Ages", p. 8
   4. **Stand is mature** 12
5. **Average tree d.b.h. is less than 2 inches** 6
   See "Stand Conditions–Size", p. 4
5. **Average tree d.b.h. is 2 inches or more** 8
   6. **400 or more trees per acre free to grow** 7
      See "Release", p. 5
   6. **Less than 400 trees per acre free to grow** . . . . . RELEASE . . 7
7. **Less than 2,000 trees per acre** 17
   See "Weeding and Cleaning", p. 6
7. **2,000 or more trees per acre** . . . . . WEED . . 17
   8. **Average tree d.b.h. is less than 5 inches** 9
      See "Stand Conditions–Size", p. 4
   8. **Average tree d.b.h. is 5 inches or more** 10

9. **Basal area is less than 160 square feet per acre** 17
See "Weeding and Cleaning", p. 6
9. **Basal area is 160 square feet or more per acre** . . . . . CLEAN . . 17

10. Basal area is less than 140 square feet per acre 11
See "Thinning", p. 7
10. Basal area is 140 square feet or more per acre . . . . . THIN . . 11

11. **Crop trees do not need pruning** 17
See "Pruning", p. 7
11. **Crop trees need pruning** . . . . . PRUNE . . 17

12. Old growth stands are needed for timber or other resources 13
See "Regulating the Forest", p. 7, and "Other Resource Conditions", p. 12
12. Old growth stands are not needed 18

13. **Temporary need until other stands mature** . . . . . EXTEND ROTATION . . 17
See "Maintaining Old Growth Stands", p. 8, and "Harvesting Methods", p. 8
13. **Continuing need for mature trees on area** . . . . . USE SELECTION

14. Site is suitable for red pine 15
See "Site Evaluation", p. 9
14. Site is not suitable for red pine . . . . . MANAGE FOR OTHER SPECIES

15. **No merchantable stand on area** 16
See "Conversion Opportunities", p. 9
15. **Merchantable stand on area** . . . . . USE CLEARCUT . . 19

16. Will have merchantable stand in 20 years or less 17
See "Productivity", p. 5
16. Will not have merchantable stand in 20 years 19

17. **Low risk of injury or loss** . . . . . WAIT
See "Risk", p. 4, and "Quality", p. 5
17. **High risk of injury or loss** . . . . . CONTROL IF FEASIBLE

18. Continuous tree cover needed . . . . . USE STRIP SHELTERWOOD . . 19
See "Harvesting Methods", p. 8
18. Continuous tree cover not needed . . . . . CLEARCUT . . 19

19. **Adequate mineral soil seedbeds free of slash and competition** 20
See "Site Preparation", p. 10
19. **Inadequate seedbeds** . . . . . PREPARE SITE . . 20

20. Easy seeding chance . . . . . DIRECT SEED
See "Seeding and Planting", p. 10
20. Poor seeding chance . . . . . PLANT

TIMBER MANAGEMENT CONSIDERATIONS

Stand Conditions

Red pine stands and potential red pine sites need to be carefully examined on the ground to best determine their condition, but use of aerial photos, maps, and other sources of information should not be overlooked. The stand – or site – condition, which is the basis for recommendations, includes type, age, size, density, risk, quality, productivity, and operability.

Type

The red pine type includes both pure red pine stands and various mixtures in which red pine is the predominant species. In addition to the species composition of the main stand, important understory tree or shrub species should be evaluated for site preparation needs and multiple use values. Nonstocked areas, poorly stocked red pine stands, and other forest types may be suitable sites to establish red pine seedlings.

Age

The age of dominant and codominant trees in even-aged stands will aid in estimating site productivity and comparing the present stand with its potential condition. Total age in red pine can be estimated by adding 8 years to age at breast height (4.5 feet above ground). Rotation ages for red pine are discussed on page 8. In uneven-aged stands, the distribution of age classes will help determine the feasibility of using the selection system. Uneven-aged stands should have three or more age classes separated by 20 years or more and will require extra effort to establish new age classes periodically by seeding or planting. Uneven-aged management of stands is not recommended except for special areas where a continuing need for mature trees will justify the extra effort required.

Size

Even-aged stands are classified as seedling stands (up to 2 inches average d.b.h.), sapling (2 to 5 inches), pole (5 to 9 inches), and sawtimber (9 inches and over). Tree diameters are strongly influenced by stand density as well as age and site (table 2, p. 15, Appendix). In managed stands with more uniform stand density, tree size will also be more uniform.

The optimum distribution of tree sizes for uneven-aged red pine stands has not been determined so records should be maintained to help control recruitment into each size class on the special areas where uneven-aged management is needed.

Stand Density

Two important aspects of stand density in even-aged stands are the stocking level and uniformity. As the stocking level decreases toward the minimum stocking, uniformity or distribution of the trees in the stand increase in importance. The minimum stocking in basal area and number of trees for perfectly uniform stands of various average stand diameters was calculated from the maximum amount of growing space trees of each diameter could use (fig. 7, p. 13, Appendix). Minimum stocking for stands averaging 5 inches in diameter is about 400 trees and 60 square feet of basal area per acre. In stands averaging 15 inches in diameter minimum stocking is about 80 trees and 100 square feet of basal area per acre. The recommended upper limit of stocking for managed stands is based on 80 percent of a normal yield table for pole stands (5 to 9 inches average diameter) and the crown diameters of forest grown trees for sawtimber stands (fig. 7, p. 13, Appendix). The recommended upper limit of stocking for managed stands averaging 5 inches in diameter is about 1,100 trees and 150 square feet of basal area per acre. For stands averaging 15 inches in diameter it is 175 trees and 215 square feet of basal area per acre.

Seedling and sapling stands (less than 5 inches average diameter) should have between 400 and 1,100 trees per acre. Fewer than 400 trees will not provide minimum recommended stocking by the time the stand reaches pole-timber size and more than 1,100 trees will exceed the upper limit of recommended stocking before the trees reach pole-timber size and can be thinned commercially.

Stand density guides for uneven-aged red pine stands have not been determined but in general the seedlings need to outnumber the saplings which in turn outnumber the pole trees which outnumber the sawtimber trees. Losses in the smaller size classes are expected and considerable effort will be needed to assure survival and growth of enough trees in each class to replace those harvested, lost, or moving up into the next larger class.

Risk of Loss from Damaging Agents

Risk depends on the degree of injury and the chances for the tree to recover from damage by disease, insects, animals, fire, or weather. Weather damage includes flooding, drought, ice and snow breakage, and lightning strikes.

A couple of diseases that have caused problems in young red pine are Scleroderris canker and red pine shoot blight. Other diseases include root rots, butt rots, and needle blights that may be important in local areas. Best control measures are to remove infected trees and provide favorable growing conditions for red pine crop trees to maintain their vigor.

Several insects may defoliate red pine including a number of sawflies, the pine tussock moth, jack pine budworm, and pine webworm. Damage to tips and buds may be caused by the European pine shoot moth, the Zimmerman pine moth, or occasionally by the white pine weevil. The Saratoga spittlebug may cause mortality of branches and entire seedlings by mechanical injury from feeding on the sap. Other insects that sometimes injure red pine are white grubs, pine root collar weevils, and bark beetles.

Insect control may involve removal of alternate host plants as in the case of sweetfern to control the Saratoga spittlebug; modifying the habitat such as pruning the lower branches to control the European pine shoot moth, and removing the duff to control the pine root collar weevil; or in some cases by using chemicals[2] to protect the trees. An entomologist should be consulted for recommended control measures.

Animal injury to red pine may be caused by deer, hare, porcupine, or mice in local areas. Measures short of animal control may not be sufficient but eliminating protective grass and shrub cover will help reduce hare and mice activity in the area.

Trees with large fire scars may be a risk for wind breakage and decay. They should be salvaged in one of the thinning operations. Young stands are susceptible to fire injury and should be protected with a fire break. A narrow strip of deciduous trees that are less flammable than red pine can be used to break up large blocks of pine. Pruned trees will reduce the risk of ground fires crowning in sapling stands. In pole-size and larger timber periodic understory burning can control build-up of fine fuels and help reduce the risk of wildfire.

Quality

Red pine tree quality is related to size, form, straightness, and a clean bole. In managed stands the poorer quality trees should be removed in the periodic thinnings favoring the best quality crop trees. Even-aged stands managed near the recommended upper limit of stand density will have less taper, smaller branches, and a greater number of trees from which to select the final crop trees. Crop trees should be low risks, free of defects, and vigorous. Stands should have 100 to 150 acceptable crop trees per acre. Clean boles can be obtained by pruning.

Productivity

Site index is used to estimate productivity of the site (see p. 9 and fig. 8, Appendix) but the productivity of the stand depends not only on the site but how well it is being used. The productivity of a stand can be estimated with the aid of the growth and yield tables in the Appendix. Yields in cubic feet, cords, and board feet are shown for site indices 45, 55, 65, and 75 feet at several different ages and for stand densities of 30, 60, 90, 120, 150, and 180 square feet of basal area per acre (tables 5, 7, and 9, Appendix). Current annual growth is also shown for these same stand conditions so that growth of any stand can be projected for the next growth period (tables 6, 8, and 10, Appendix). If projections are made for more than 10 years, it would be best to interpolate a new current annual growth from the table or use the equations given in the table to compute the periodic annual growth for the period.

[2] *See Pesticide Precautionary Statement, p. 21.*

Operability

Markets, access, and volume of products that can be removed in a thinning or final harvest determine operability. The minimum volume required depends to a large extent on the value of the product so that managing a stand for higher value products will usually make it operable with lower volumes. Harvested volume per landing is more important than the volume per acre in determining operability. One landing of about 1/2 acre is recommended for up to 40 acres in managed stands. Although 40 acres is the recommended area for establishing new stands on large forest ownerships, minimum size for general forest management is 10 acres. Smaller areas can be managed to meet special needs or owner's objectives but costs will usually be higher.

Controlling Composition and Growth

Red pine trees grow best in full sunlight; that is, they are intolerant of overhead shade. In mixed stands with species less tolerant than red pine such as jack pine and aspen, red pine growth is reduced by the shading from the trees that have faster height growth as seedlings and saplings. In mixed stands with more tolerant species red pine may be crowded out by the severe competition. Cultural practices can be used to keep the red pine crop trees free from overhead shade and to provide the needed growing space for rapid growing, high quality trees.

Release

Complete release of red pine seedlings from shrubs and other low competition may be needed by the end of the third growing season. Cutting by hand requires a lot of labor and regrowth of the competition may necessitate several cuttings at 2- or 3-year intervals. The most practical release method where there are more than just a few trees or shrubs is chemical control with broadcast foliage sprays.

Two of the most useful herbicides are 2,4-D and 2,4,5-T. These two chemicals can control most of the

deciduous woody competition without injuring red pine if spraying is done soon after pine leader growth is complete and the terminal bud is set, around mid-July. Spraying should be completed before the middle of August for best control of hardwoods. Most of the common competing species can be controlled with 2,4-D but blackberries, raspberries, roses, juneberries, prickly ash, oaks, and maples are resistant to it. All of these species except the maples can be controlled with 2,4,5-T. Maples are difficult to control with foliar sprays but felling the tree and spraying the stump with chemicals containing 2,4,5-T is effective. The use of chemical herbicides requires strict adherance to label instructions.[2]

Planting red pine under hardwood overstories is not recommended because serious growth losses occur with even a light overstory (fig. 9, Appendix). Plantations with hardwood overstory should be released as soon as possible (fig. 1). Merchantable overstory trees may be harvested and unmerchantable trees felled, girdled, or poisoned. Chemicals can be sprayed on the lower 2 feet of the bole on trees up to 3 inches in diameter, injected into frill girdles or basal cuts on larger trees, or sprayed on the foliage as done for control of low competition.

Figure 1. – *Red pine trees need complete release from overhead shade for best growth.*

Weeding and Cleaning

Seedling stands with over 2,000 trees per acre and sapling stands that have over 160 square feet of basal area per acre should be weeded or cleaned by a precommercial thinning. Weeding is done during the seedling stage of stand development and cleaning during the sapling stage. These operations provide adequate growing space for the potential crop trees and maintain their rapid diameter growth. Red pine stands that have been established by natural seeding, direct seeding, or planting at close spacings will usually benefit from these operations.

Clearing strip roads about 12 feet wide at intervals of 50 to 60 feet will provide access into the stand for weeding, cleaning, and future thinnings (fig. 2). In seedling stands (less than 2 inches average diameter) having more than 2,000 trees per acre, at least 100 potential crop trees per acre should be given a minimum growing space of 25 square feet each. Up to half of the crop trees may be located along the strip roads and the other half should be between them at approximately 20-foot spacings.

Densely stocked sapling stands (2 to 5 inches average diameter) with 160 square feet of basal area or more per acre should be cleaned. Cleared strip roads are recommended to provide access. Crop trees in sapling stands should be given about 50 square feet of growing space per tree to maintain good diameter growth.

Figure 2. – *Clearing strip roads in young stands will facilitate precommercial thinning and provide access for future cultural operations throughout the rotation.*

Thinning

One of the most important ways stand composition and development can be controlled is by periodic commercial thinnings (fig. 3). Stands should be thinned before they exceed the recommended upper limit of stocking for managed stands (fig. 7, Appendix). A uniform distribution of the best quality trees with at least the minimum recommended stocking for the average stand diameter should be left, but not over half – and preferably less – of the basal area should be removed in any one thinning. Stands managed near the minimum recommended stocking will have the most rapid diameter growth but the opportunity for selecting crop trees will be more limited because of the fewer trees per acre. As a more general guide, pole stands (5 to 9 inches average diameter) should be considered for thinning when the basal area is 140 square feet or more per acre and they should be thinned to leave about 90 square feet.

Figure 3. – *Periodic thinning of red pine stands can provide useful products and control the growth and development of the final crop trees.*

If a system of access trails for management of the stand has not already been developed during precommercial thinning, it should be done during the first commercial thinning. Removal of complete rows in plantations may serve as strip roads but more often than not strips should cross some rows to provide the most useful access into and out of the stand from the landing or working area. A convenient spacing for access strips is 50 to 60 feet which will usually leave a good supply of trees between strips from which to select the crop trees.

Thinnings between access strips should generally be from below to remove the smaller, slower growing intermediate and codominant trees and favor the larger crop trees, but high risk, poor quality, or damaged trees should also be removed. In some dense stands where only the largest trees are merchantable, a commercial thinning would require thinning from above. This is preferable to delaying the first thinning in very dense stands because growth loss from crowding may be even greater. Row thinning is also an alternative that may be considered for the first thinning but all other thinnings should be from below.

Sawtimber trees should be thinned periodically to maintain uniform growth rates on the crop trees. Small sawtimber stands (9 to 15 inches average diameter) grow well at densities around 120 square feet of basal area per acre. Larger sawtimber stands also grow well at these densities but the fewer, larger trees will be using less of the growing space because the crown area of large forest grown trees doesn't increase at the same rate as their basal area. Sawtimber stands averaging 15 inches d.b.h. or more can be managed at densities of 150 or even 180 square feet of basal area per acre (150 or fewer trees) without serious crowding.

In mixed stands red pine crop trees should be favored in each thinning but other species should be left where needed to maintain uniform spacing and avoid large openings.

Pruning

Managed red pine stands that are thinned regularly to provide adequate growing space for the crop trees, especially those managed near the minimum recommended stocking, will need artificial pruning to produce high quality, strong, clear wood. Crop trees should be pruned when they are pole size (5 to 9 inches average diameter) (fig. 4). Branches should be cut off flush with the bole to facilitate rapid healing of wounds. Wounds up to 1 inch will heal over in 5 years or less on healthy trees. Prune live branches no higher than half of the tree's total height. Mechanical pruners are more efficient than hand pruning above 12 feet and will usually be necessary to prune higher than 17 feet.

Regulating the Forest

Forest regulation involves long range planning to assure a continuous systematic development of forest stands and a more uniform flow of useful products. Some important aspects of forest regulation are harvesting

Figure 4. – *The production of high quality, strong, clear wood can be increased by pruning the final crop trees in red pine pole stands.*

methods, rotation ages, maintaining old growth stands, and conversion opportunities.

Harvesting Methods

Silvicultural systems are named after the method of harvesting the final crop trees and preparing the site for establishing a new forest stand. Even-aged silvicultural systems that have been used for managing red pine are clearcutting, seed tree, and shelterwood. Clearcutting is recommended where mature trees are not needed on the area. The seed tree system which has not proved successful because seed crops are infrequent is not recommended. Shelterwood systems also have the same disadvantage but they are recommended where mature trees are needed on the area to bridge the gap from a fully stocked stand of mature trees to a fully stocked stand of seedlings established by planting. If the shelterwood trees are left in narrow strips they can be removed later without damaging the sapling stand. Even-aged systems need a series of different age stands to provide a periodic flow of products and uses. In developing this range of age classes it may be desirable to harvest some stands at younger ages and others at older ages as discussed under "Rotation Ages".

Uneven-aged silvicultural systems include selection or group selection cuttings. Although red pine is not as well suited to these systems as it is to the even-aged systems, careful cutting of mature trees and frequent release of seedling, sapling, and pole trees makes it possible to grow several age classes in small groups where continuous high forest cover is needed or desired. These systems may also be appropriate for a more even flow of products and uses from small areas where it is not possible to have enough different age classes of even-aged stands.

Rotation Ages

Red pine is a long-lived tree providing the opportunity to grow stands to about 200 years where needed. But with periodic thinnings to the minimum recommended basal area densities, the average tree can reach 20 inches in diameter on the best sites in about 60 years. Culmination of mean annual board foot growth in stands periodically thinned to the *same* basal area density depends on the basal area left after the thinnings (table 11, Appendix). Growth culminates earlier in stands periodically thinned to basal area levels below the minimum recommended stocking but total stand growth is also lower. Growing stands at higher densities (about 120 square feet of basal area) on longer rotations (120 to 140 years) will produce a higher annual growth and yield. The rotation age for sawtimber should be set within this biological range of 60 to 200 years on the basis of other needs and considerations. One need might be to adjust the distribution of age classes for regulating the forest. In areas that lack old growth stands, some young stands could be managed at low densities and short rotations to supply needed sawtimber for the short run. Where old growth stands are available, the rotations of some stands may be extended to allow time for younger stands to reach sawtimber size.

Maintaining Old Growth Stands

Extending rotations to allow young stands of pole-timber to reach sawtimber size should be limited to healthy, vigorous stands that have at least the minimum recommended stocking (fig. 7, Appendix). Higher stocking is desirable to maintain good growth in old stands because the height growth is very low. Basal area growth also decreases with age but is still over 2 feet per acre per year for the higher density stands on the better sites (table 4, Appendix). Old growth stands should have only light salvage cuts to keep them healthy and vigorous and to prevent the development of dense shrub understories. Old growth stands should be harvested by 200 years of age and new stands established in the same manner as recommended for mature stands.

Conversion Opportunities

In building the red pine resource for the future, new stands should be established as rapidly as possible so the forest will be fairly well regulated as the stands mature. Red pine should be restored on former pine land that is now poorly stocked or stocked with less desirable species. Conversion of nonstocked brush areas and aspen or oak types to red pine on a regular basis will establish a fully regulated red pine forest in one rotation. Priorities for conversion will vary somewhat with the forest owner's objective and capabilities, but general recommendations are nonstocked areas, poorly stocked mature stands, other mature stands, poorly stocked immature stands, and other immature stands, in that order. Stands with a lot of high risk or low quality trees should be converted before stands with fewer such trees. Conversion of stands that will be merchantable in 20 years or less should be delayed so the harvesting operation can help clear the site and aid the job of site preparation.

Controlling Stand Establishment

Site Evaluation

Before establishing a red pine stand, some estimate of its potential growth on the area should be obtained. If there are red pine trees over 30 years old on the area that have never been suppressed, the best estimate of site index is from site index equations or curves based on the total height and total age of the dominant and codominant trees (fig. 8, Appendix).

Red pine trees starting at about 15 years of age can also provide good estimates of site index based on the following tabulation:

Length of 5 internodes above 8 feet	Site index[3]
(Feet)	(Feet)
4	38
5	46
6	52
7	56
8	61
9	65
10	68
11	72
12	76

[3] *Based on a revised equation adapted from Alban (1972); site index = 36.9 + 3.356(x) - 192.474 $(x)^{-2}$; where x equals length of 5 internodes above 8 feet.*

Other growth intercept methods based on 1 to 5 years' growth above breast height (4.5 feet) have been used but estimates of site index are less reliable. Their advantage is that they can be used on red pine trees with only a few years' growth above breast height. The following simplified tabulation shows approximate site index based on average annual height growth for one to five years above breast height:

Average annual height growth above breast height	Approximate site index[4]
(Inches)	(Feet)
10	45
13	55
17	65
24	75

Considerable variation in annual growth can be expected from year to year so whenever possible the full 5 years' growth should be measured to obtain the average annual growth for estimating site index. Site index will be slightly underestimated when based on 1 year's average and slightly overestimated when based on the average of 5 years' growth using this table.

Site index for red pine can also be estimated from the site index of other trees growing on the area if they have not been suppressed. Jack pine, white pine, white spruce, or aspen site index can be used to estimate red pine site index as in the following generalized tabulation:

Red pine[5]	Jack pine	White pine	White spruce	Aspen
		(Feet)		
45	50	45	35	40
55	60	55	50	60
65	70	65	65	80
75	80	75	80	100

If no suitable trees are available for site index measures, soil properties can be used to estimate red pine site index on sand to sandy loam soils (table 1, Appendix). The factors needed are the depth of the A and B horizons, the percent gravel in the surface 10 inches, and the presence or absence of finer textured soil bands or layers totaling at least 6 inches within 8 feet of the surface. These factors will permit estimates of site

[4] *Adapted from Day* et al. *(1960), and Schallau and Miller (1966).*

[5] *Adapted from Carmean and Vasilevsky (1971), and Alban (1976).*

index for red pine on sand to sandy loam soils where red pine is recommended. Other species such as white spruce, aspen, or northern hardwoods are usually recommended on finer textured soils.

In evaluating sites for red pine it is important to remember that site index predicts the height of dominant trees in a stand at 50 years of age and must be related to yields before comparing productivity between species. For example, side-by-side stands of 40-year-old red pine and jack pine growing on a fine sandy loam had site indices of 68 and 70 feet, respectively, but the red pine stand had 55 percent more total cubic foot volume than the jack pine stand. The red pine stand had grown to 225 square feet of basal area per acre compared to only 152 square feet in the jack pine stand.

Another important part of site evaluation is determining the need for site preparation to establish a new stand. Generally the higher the site quality the greater the need to control competing sod, shrubs, and trees to favor the establishment of red pine.

Site Preparation

A good job of site preparation should eliminate competition for light, water, and nutrients without causing any serious risk of soil loss (fig. 5). Minimum site preparation of only seeding or planting spots offers the most site protection but may require frequent follow-up release of the pine seedlings. Complete site preparation will reduce the need for follow-up release but may expose the site to erosion, severe drying, or be an eyesore. On some areas full-tree skidding to remove slash may be all the site preparation needed but on most areas shrubs should be controlled and mineral soil exposed.

Figure 5. – *A thorough job of site preparation favors the establishment of red pine seedlings.*

Mechanical equipment, herbicides, prescribed burning, or a combination may be used for site preparation. The use of mechanical equipment depends on the job that needs to be done and the availability of equipment. Some of the common kinds of equipment used to prepare sites for red pine establishment are bulldozers, shearing blades, heavy duty discs, rototillers, plows, root rakes, rock rakes, drum choppers, and many kinds of homemade scarifiers to knock down the shrubs and loosen the soil. Under some conditions the loosened soil may be difficult to properly pack around planted seedlings resulting in a high rate of mortality.

The most commonly used herbicides to control shrubs and hardwoods are the same ones used for seedling release – 2,4-D and 2,4,5-T.[2] Foliar spraying should be done as soon as the shoot growth is complete, when it is the most effective, about mid-July in northern Minnesota and a little earlier further south. Grass and herbaceous plants can be controlled with Amitrol[2] or Dalapon,[2] and Simazine[2] can be used to prevent regrowth during the year. Follow-up treatments may be needed the next year especially on areas of heavy sod.

Prescribed burning is usually most effective for site preparation soon after harvesting when slash accumulations provide plenty of fuel for a hot fire. Conifer slash can be burned almost immediately but hardwood slash needs to cure for several weeks to get good results. In mature red pine stands one or more summer fires can be prescribed to eliminate the shrubs and reduce the depth of organic material on the seedbeds prior to harvesting (fig. 6). Burning plans should be approved and permits obtained where required.

Seeding and Planting

Natural seeding during good seed years can successfully establish seedlings on seedbeds such as those prepared by summer prescribed burning under a mature stand of red pine. Scarifying the soil may also be successful if shrubs are not present. Red pine seed years, however, are so infrequent that seed should be collected during good seed years for direct seeding or growing seedlings to plant.

Figure 6. – *Controlled summer fires can eliminate most of the woody understory in red pine stands before harvesting and help prepare favorable conditions for establishing red pine seedlings at the end of the rotation.*

Direct seeding has not enjoyed widespread success, but in northeast Minnesota it has been successful on well prepared sites if frequent rain storms occur during the first few months after germination. Seed should be coated with bird and rodent repellants and sown at the rate of 15,000 viable seeds per acre (about 5 ounces) early in the spring to take advantage of snowmelt waters for germination. Somewhat better results have been experienced by covering red pine seed with 1/4 inch of soil but it may be more expedient to broadcast more seed on the surface than to use less seed and cover it. It is easier to cover the seed when sowing 5 to 10 seeds in prepared spots. Even though direct seeding can be successful it generally has not been because of inadequate site preparation, inadequate precipitation, or loss of seeds to birds or rodents.

The most reliable method of establishing a red pine stand is to plant nursery-grown trees. Planting of bare root stock should be done in the spring setting the trees at least as deep as they grew in the nursery. On drier sites planting trees up to 2 inches deeper may be beneficial, but planting trees too deep increases the risk of injury by root collar weevils. The more difficult sites should be planted with bare root transplant stock or large vigorous seedlings. Container-grown trees show promise for planting throughout the growing season.

The spacing of planted trees determines how the trees will develop during their early years and how soon the stand will close in and affect the ground cover. Spacings closer than 5 feet will not provide the minimum growing space recommended for seedlings, and spacings greater than 10 feet will not provide the minimum number of seedlings recommended per acre. The time to reach pole size (5 inches diameter) will vary from 15 to 30 or more years depending mostly on the spacing or number of trees per acre established and to a lesser extent on the site quality (table 2, Appendix). The closer spacings will require cleaning (precommercial thinning) during the sapling stage (2 to 5 inches average diameter) to provide the recommended 50 square feet of growing space for each crop tree, and the wider spacings may need an extra release or two to control grass, shrub, and hardwood competition.

Planting recommendations depend on many things including the forest owner's objective, planting chance, and management intensity. Planting 400 trees per acre (a little more than 10- by 10-foot spacing) will be the least costly, crop trees will have rapid diameter growth, commercial thinnings can be made by the time trees need more growing space, and crown closure will not shade out ground vegetation for about 20 years. Planting 1,600 trees per acre (a little more than 5- by 5-foot spacing) will allow greater flexibility in selecting crop trees and controlling early stand development, crop trees will have less taper and smaller branches, and the stand will have more total volume.

Trees should be planted at wide spacings up to 10 by 10 feet if: all or most of the planted trees have a good chance of surviving, precommercial thinnings are not feasible (or not planned), and favoring ground vegetation is a management objective. On the other hand trees should be planted at close spacings down to 5 by 5 feet if: tree quality such as taper and branch size is important, early crown closure to suppress competition is desired, precommercial and early thinnings are planned to control stand development, and frequent thinnings are wanted throughout the rotation. Most plantations will be established at spacings between these two extremes. Commonly used spacings are 6 by 8 and 6 by 10 feet. Machine planting costs can be reduced by using wider rows and closer spacing of trees in the row but plans for access and future management operations should also be considered at the time of stand establishment.

OTHER RESOURCE CONDITIONS

Recreation

Red pine stands are popular places for hiking, camping, and other recreational activities especially when the trees are large and located near a lake or stream. Management considerations for recreation should include long rotations to maintain a higher proportion of the forest in large, old-growth trees. For example, a fully regulated red pine forest with rotation ages of 150 years would have two-thirds of the area in stands over 50 years old compared to only half the area if 100-year rotations were used. Young stands should be managed near the minimum recommended stocking to obtain large trees as soon as possible but older stands should be managed nearer the upper limits to reduce development of unwanted understory plants and increase the opportunity to extend the rotation. New stands should be established regularly to provide continuous stands of large old growth trees for the future. Understory development in large old-growth stands may be controlled to enhance the park-like appearance of recreation areas.

Operations in stands with high recreational value should be done during periods of minimal use. Recreational users should be informed about management operations and encouraged to rotate their use as the mature stands complete their cycle. In some special areas it may be necessary to use uneven-aged management to maintain a continuous stand of mature trees. On these areas considerable work will be necessary to bring through the required number of seedling, sapling, and poletimber trees to replace the mature trees as they are periodically removed.

Water

Red pine forests usually cover only a part of a watershed so management activities should be coordinated with those on other areas in the watershed to maintain an even flow of high quality water. Stands managed near the minimum recommended stocking will have higher water yield. Care is needed in harvesting trees near streams and lakes to prevent soil and debris from getting into the water. Some stream crossings may require culverts. Landings should be carefully planned and trails should be kept back away from shorelines and streambanks to prevent soil from eroding into the water. Trees should be felled away from the water and winched to the nearest skid trail. Intermittent stream channels should not be used for skidding. Timber harvesting when soils are frozen will reduce erosion hazards on some areas.

Wildlife

Red pine stands are generally considered poor habitat for game birds and animals but they provide cover and nesting sites for many species of wildlife. Large old-growth trees are used by the American bald eagle as well as many songbirds.

Although red pine stands offer good shelter for wildlife, many of the favored food plants are not found in the understory. Managing stands near the minimum recommended stocking will favor a greater variety of understory plants. Prescribed burning may also be effective in developing a more favorable understory for wildlife food. Carefully planned landings can serve as wildlife openings providing some of the food plants needed. Landings should be at least 1/2 acre for an effective wildlife opening.

APPENDIX

Stocking Chart

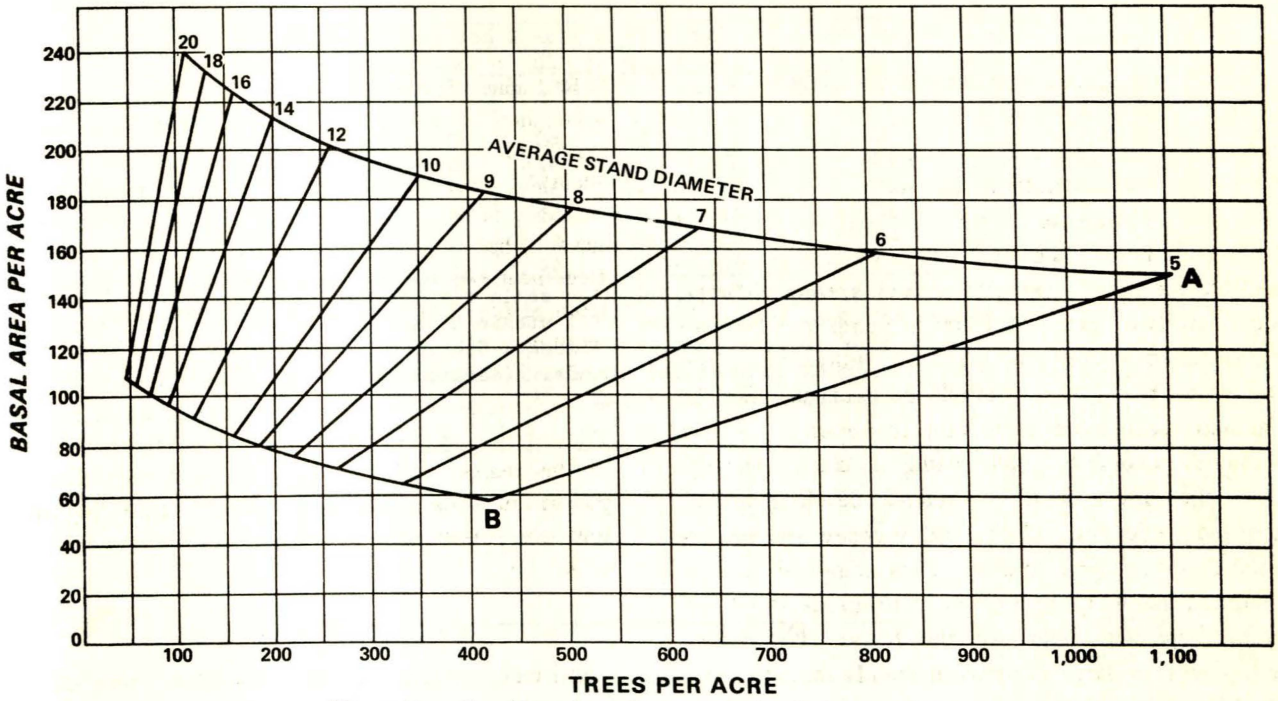

Figure 7. – *Stocking chart for managed red pine stands.*

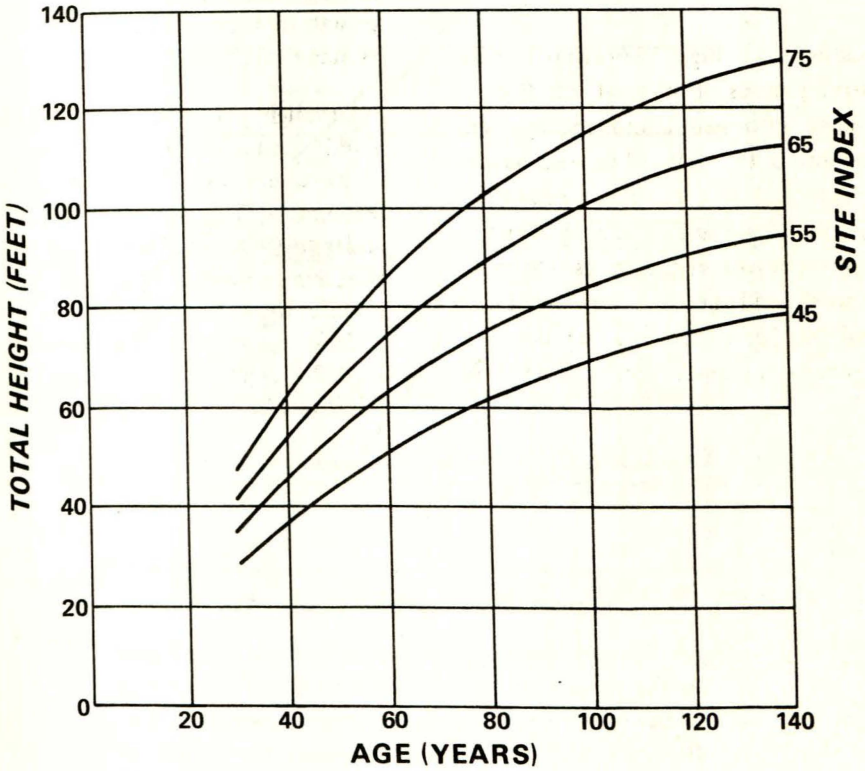

Figure 8. – *Red pine site index curves. Based on the equation: height = site index (1.956 - 2.1757 e $^{-0.01644(age)}$) (Lundgren and Dolid 1970).*

Table 1. – *Estimated site index for red pine plantations in the Lake States on well drained sand to sandy loam soils*[1]

Gravel or rocks in top 10 inches	Depth of A plus B horizons (inches)					
	5	10	20	30	40	50
Percent by weight	*Site Index (Feet)*					
0	55	57	60	63	67	70
10	52	54	57	60	63	67
20	49	51	54	57	60	63
30	46	48	51	54	57	60
40	43	45	48	51	54	57
50	40	41	44	48	51	54

[1]Add 5 feet to site index on soils with bands or layers of finer textured material within 8 feet of the surface that improve water relations. Subtract 5 feet from site index for natural stands. (Adapted for the Lake States from Alban (1976).)

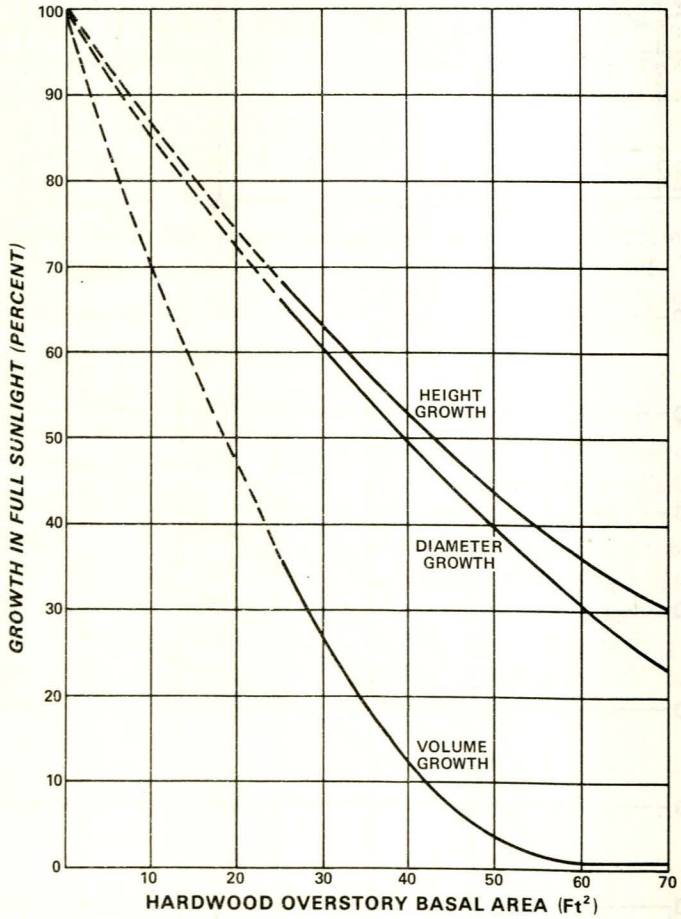

Figure 9. – *Influence of hardwood overstory basal area on the growth of planted red pine. Based on red pine release studies in nine plantations ranging from 2 to 40 years old on medium to good sites in Lower Michigan. Cooley, J. 1975. Unpublished report on file at North Central Forest Experiment Station, Grand Rapids, Minnesota.*

Table 2. – *Average d.b.h. of young red pine stands*[1]

Total age	Total height	Number of trees per acre: 400	800	1200	1600	2000
Years	*Feet*	*Inches*				
SITE INDEX 75						
15	21	5.2	4.5	3.9	3.5	3.2
20	30	6.5	5.6	4.9	4.4	4.0
25	38	7.4	6.4	5.6	5.0	4.5
30	46	8.2	7.0	6.1	5.5	5.0
SITE INDEX 65						
15	19	4.7	4.0	3.5	3.2	2.9
20	26	6.0	5.1	4.5	4.0	3.6
25	33	6.9	5.9	5.2	4.6	4.2
30	40	7.5	6.5	5.7	5.1	4.6
SITE INDEX 55						
15	16	4.2	3.6	3.2	2.8	2.6
20	22	5.4	4.6	4.0	3.6	3.3
25	28	6.2	5.4	4.7	4.2	3.8
30	34	6.9	5.9	5.2	4.6	4.2
SITE INDEX 45						
15	13	3.6	3.1	2.7	2.4	2.2
20	18	4.8	4.1	3.6	3.2	2.9
25	23	5.6	4.8	4.2	3.7	3.4
30	28	6.2	5.3	4.8	4.1	3.8

[1]Computed from table 3 as diameter of tree of average basal area.

Table 3. – *Estimated basal area*[1] *of young red pine stands*

Total age	Total height	Number of trees per acre: 400	800	1200	1600	2000
Years	*Feet*	*Square Feet*				
SITE INDEX 75						
15	21	59	87	101	107	110
20	30	93	136	157	167[2]	171
25	38	121	178	205	218	224
30	46	145	214	246	261	268
SITE INDEX 65						
15	19	48	71	82	87	89
20	26	78	114	131	140	143
25	33	103	151	174	185	190
30	40	124	183	210	223	229
SITE INDEX 55						
15	16	38	56	65	69	71
20	22	63	93	107	114	117
25	28	85	125	144	153	157
30	34	103	152	175	186	191
SITE INDEX 45						
15	13	29	43	49	52	54
20	18	50	73	84	90	92
25	23	68	100	115	122	125
30	28	83	122	141	150	154

[1]Based on the equation $B = 6.565302(S)(1-e^{-.0401718(BHA)})^{1.1677(1-e^{-.0018854N})}$ where B = basal area, S = site index, BHA = breast height age, and N = number of trees established. Breast height age = total age - 10.5 +0.05(site). Equations were developed by A. L. Lundgren from data collected by R. F. Wambach (1967).

[2]Thinnings are recommended for the stands shown enclosed.

Table 4. — *Current annual basal area growth per acre*[1] *for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	*Square Feet*					
SITE INDEX 75							
20	30	6.2	6.9	7.4	7.6	7.6	7.2
40	61	4.9	5.7	6.2	6.4	6.3	5.9
60	86	3.8	4.6	5.1	5.3	5.2	4.8
80	103	2.9	3.7	4.2	4.4	4.3	3.9
100	115	2.2	3.0	3.5	3.7	3.6	3.2
120	124	1.6	2.4	2.9	3.1	3.0	2.7
140	130	1.3	2.1	2.6	2.8	2.7	2.3
160	134	1.1	1.9	2.4	2.6	2.5	2.1
SITE INDEX 65							
20	26	5.5	6.3	6.8	7.0	6.9	6.5
40	53	4.2	5.0	5.5	5.7	5.6	5.3
60	74	3.2	4.0	4.4	4.6	4.6	4.2
80	89	2.3	3.1	3.5	3.8	3.7	3.3
100	100	1.5	2.3	2.8	3.0	2.9	2.6
120	107	1.0	1.8	2.3	2.5	2.4	2.0
140	112	.6	1.4	1.9	2.1	2.0	1.7
160	116	.5	1.3	1.8	2.0	1.9	1.5
SITE INDEX 55							
20	22	4.9	5.7	6.2	6.4	6.3	5.9
40	45	3.6	4.4	4.9	5.1	5.0	4.6
60	63	2.5	3.3	3.8	4.0	3.9	3.5
80	76	1.6	2.4	2.9	3.1	3.0	2.6
100	85	.9	1.7	2.2	2.4	2.3	1.9
120	91	.4	1.1	1.6	1.9	1.8	1.4
140	95	--	.8	1.3	1.5	1.4	1.0
160	98	--	.6	1.1	1.3	1.2	.8
SITE INDEX 45							
20	18	4.2	5.0	5.5	5.7	5.6	5.2
40	37	3.0	3.7	4.2	4.5	4.4	4.0
60	51	1.9	2.7	3.2	3.4	3.3	2.9
80	62	1.0	1.8	2.3	2.5	2.4	2.0
100	69	.2	1.0	1.5	1.7	1.6	1.3
120	74	--	.5	1.0	1.2	1.1	.7
140	78	--	.1	.6	.8	.8	.4
160	80	--	--	.5	.7	.6	.2

[1] $BA\ growth = 1.6889 + .041066\,(BA) - .0016303\,(BA)^2 - .076958\,(Age) + .00022741\,(Age)^2 + .06441\,(Site\ Index)$ (Buckman 1962).

Table 5. — *Volume*[1] *in cubic feet per acre for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	*Cunits (100 cubic feet) per acre*[2]					
SITE INDEX 75							
20	30	3.7	7.3	11.0	14.7	18.4	22.0
40	61	7.5	14.9	22.4	29.9	37.3	44.8
60	86	10.5	21.0	31.6	42.1	52.6	63.2
80	103	12.6	25.2	37.8	50.4	63.0	75.6
100	115	14.1	28.2	42.2	56.3	70.4	84.5
120	124	15.2	30.4	45.4	60.7	75.9	91.1
140	130	15.9	31.8	47.7	63.6	79.6	95.5
160	134	16.4	32.8	49.2	65.6	82.0	98.4
SITE INDEX 65							
20	26	3.2	6.4	9.5	12.7	15.9	19.1
40	53	6.5	13.0	19.5	25.9	32.4	38.9
60	74	9.0	18.1	27.2	36.2	45.3	54.3
80	89	10.9	21.8	32.7	43.6	54.5	65.4
100	100	12.2	24.5	36.7	49.0	61.2	73.4
120	107	13.1	26.2	39.3	52.4	65.5	78.6
140	112	13.7	27.4	41.1	54.8	68.5	82.2
160	116	14.2	28.4	42.6	56.8	71.0	85.2
SITE INDEX 55							
20	22	2.7	5.4	8.1	10.8	13.5	16.2
40	45	5.5	11.0	16.5	22.0	27.5	33.0
60	63	7.7	15.4	23.1	30.8	38.6	46.3
80	76	9.3	18.6	27.9	37.2	46.5	55.8
100	85	10.4	20.8	31.2	41.6	52.0	62.4
120	91	11.1	22.3	33.4	44.6	55.7	66.8
140	95	11.6	23.2	34.9	46.5	58.1	69.8
160	98	12.0	24.0	36.0	48.0	60.0	72.0
SITE INDEX 45							
20	18	2.2	4.4	6.6	8.8	11.0	13.2
40	37	4.5	9.1	13.6	18.1	22.6	27.2
60	51	6.2	12.5	18.7	25.0	31.2	37.4
80	62	7.6	15.2	22.8	30.4	37.9	45.5
100	69	8.4	16.9	25.3	33.8	42.2	50.7
120	74	9.1	18.1	27.2	36.2	45.3	54.3
140	78	9.5	19.1	28.6	38.2	47.7	57.3
160	80	9.8	19.6	29.4	39.2	49.0	58.8

[1]Cubic feet = 0.4085 (Basal area x Height) (Buckman 1962).

[2]Total main stem volume in cunits from 6-inch stump to tip of tree. Estimated cunits to a 4-inch top d.i.b. can be obtained by subtracting

$$1.067\left(\frac{\text{Basal area per acre in sq. ft.}}{\text{ave. tree diameter in inches squared}}\right)$$

Table 6. — *Current annual cubic foot growth*[1] *per acre for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	*Cubic feet*					
SITE INDEX 75							
20	30	101	131	158	182	203	218
40	61	142	180	210	232	246	253
60	86	147	188	218	237	246	244
80	103	131	174	204	221	225	217
100	115	110	154	184	199	200	188
120	124	85	129	158	172	171	159
140	130	72	117	146	159	156	137
160	134	63	109	139	152	149	130
SITE INDEX 65							
20	26	80	108	132	152	169	183
40	53	108	140	166	185	198	206
60	74	109	144	168	185	196	195
80	89	92	128	150	168	172	165
100	100	66	104	130	143	143	136
120	107	48	86	112	124	124	110
140	112	30	69	94	106	104	93
160	116	25	64	89	100	96	78
SITE INDEX 55							
20	22	61	83	103	119	133	144
40	45	80	107	129	145	155	160
60	63	75	106	128	143	151	150
80	76	56	87	109	121	124	118
100	85	36	69	91	103	105	96
120	91	19	48	71	86	86	74
140	95	--	36	58	68	67	54
160	98	--	26	48	57	54	39
SITE INDEX 45							
20	18	45	63	79	93	105	114
40	37	56	77	94	109	117	121
60	51	47	72	90	101	106	105
80	62	30	56	73	83	86	80
100	69	9	36	53	63	64	59
120	74	--	20	38	46	46	36
140	78	--	6	23	30	32	20
160	80	--	--	20	28	26	14

[1]Cubic feet growth = 0.4085 (basal area growth x height + height growth x basal area + basal area growth x height growth) (Buckman 1962).

Table 7. — *Volume in cords per acre*[1] *for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density basal area per acre[2] 30	60	90	120	150	180
Years	*Feet*	*Cords*					
SITE INDEX 75							
40	61	7.2	14.5	21.7	29.0	36.2	43.5
60	86	10.2	20.4	30.6	40.8	51.0	61.3
80	103	12.2	24.5	36.7	48.9	61.2	73.4
100	115	13.6	27.3	41.0	54.6	68.3	81.9
120	124	14.7	29.4	44.2	58.9	73.6	88.3
140	130	15.4	30.9	46.3	61.7	77.2	92.6
160	134	15.9	31.8	47.7	63.6	79.6	95.5
SITE INDEX 65							
40	53	6.3	12.6	18.9	25.2	31.5	37.8
60	74	8.8	17.6	26.4	35.1	43.9	52.7
80	89	10.6	21.1	31.7	42.3	52.8	63.4
100	100	11.9	23.7	35.6	47.5	59.4	71.2
120	107	12.7	25.4	38.1	50.8	63.5	76.2
140	112	13.3	26.6	39.9	53.2	66.5	79.8
160	116	13.8	27.5	41.3	55.1	68.9	82.6
SITE INDEX 55							
40	45	5.3	10.7	16.0	21.4	26.7	32.0
60	63	7.5	15.0	22.4	29.9	37.4	44.9
80	76	9.0	18.0	27.1	36.1	45.1	54.1
100	85	10.1	20.2	30.3	40.4	50.5	60.5
120	91	10.8	21.6	32.4	43.2	54.0	64.8
140	95	11.3	22.6	33.8	45.1	56.4	67.7
160	98	11.6	23.3	34.9	46.5	58.2	69.8
SITE INDEX 45							
40	37	4.4	8.8	13.2	17.6	22.0	26.4
60	51	6.1	12.1	18.2	24.2	30.3	36.3
80	62	7.4	14.7	22.1	29.4	36.8	44.2
100	69	8.2	16.4	24.6	32.8	41.0	49.2
120	74	8.8	17.6	26.4	35.1	43.9	52.7
140	78	9.3	18.5	27.8	37.0	46.3	55.6
160	80	9.5	19.0	28.5	38.0	47.5	57.0

[1]Cords = 0.003958 (Basal area x Height). Rough cords for trees 3.6 inches DBH and larger to a 3-inch top d.i.b. (Buckman 1962).

[2]Must be in trees 3.6 inches DBH and larger.

Table 8. — *Current annual cordwood growth per acre*[1] *for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre[2] 30	60	90	120	150	180
Years	*Feet*	*Cords*					
SITE INDEX 75							
40	61	1.3	1.7	2.0	2.2	2.4	2.4
60	86	1.4	1.8	2.1	2.3	2.4	2.4
80	103	1.3	1.7	2.0	2.1	2.2	2.1
100	115	1.1	1.5	1.8	1.9	1.9	1.8
120	124	.8	1.2	1.5	1.7	1.6	1.5
140	130	.7	1.1	1.4	1.5	1.5	1.3
160	134	.6	1.0	1.3	1.5	1.4	1.3
SITE INDEX 65							
40	53	1.0	1.4	1.6	1.8	1.9	2.0
60	74	1.1	1.4	1.6	1.8	1.9	1.9
80	89	.9	1.2	1.5	1.6	1.7	1.6
100	100	.6	1.0	1.3	1.4	1.4	1.3
120	107	.5	.8	1.1	1.2	1.2	1.1
140	112	.3	.7	.9	1.0	1.0	.9
160	116	.2	.6	.9	1.0	.9	.8
SITE INDEX 55							
40	45	.8	1.0	1.2	1.4	1.5	1.5
60	63	.7	1.0	1.2	1.4	1.5	1.5
80	76	.5	.8	1.1	1.2	1.2	1.1
100	85	.4	.7	.9	1.0	1.0	.9
120	91	.2	.5	.7	.8	.8	.7
140	95	--	.3	.6	.7	.6	.5
160	98	--	.3	.5	.6	.5	.4
SITE INDEX 45							
40	37	.5	.7	.9	1.0	1.1	1.2
60	51	.5	.7	.9	1.0	1.0	1.0
80	62	.3	.5	.7	.8	.8	.8
100	69	.1	.3	.5	.6	.6	.6
120	74	--	.2	.4	.4	.4	.3
140	78	--	.1	.2	.3	.3	.2
160	80	--	--	.2	.3	.2	.1

[1]Cordwood growth = .003958 (basal area growth x height + height growth x basal area + basal area growth x height growth) (Buckman 1962).

[2]Must be in trees 3.6 inches DBH and larger.

Table 9. — *Volume in M board feet per acre*[1] *for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre[2] 30	60	90	120	150	180
Years	*Feet*	*M Board feet*					
SITE INDEX 75							
60	86	5.4	10.8	16.1	21.5	26.9	32.3
80	103	6.4	12.9	19.3	25.8	32.2	38.6
100	115	7.2	14.4	21.6	28.8	35.9	43.1
120	124	7.8	15.5	23.3	31.0	38.8	46.5
140	130	8.1	16.3	24.4	32.5	40.6	48.8
160	134	8.4	16.8	25.1	33.5	41.9	50.3
SITE INDEX 65							
60	74	4.6	9.2	13.9	18.5	23.1	27.8
80	89	5.6	11.1	16.7	22.3	27.8	33.4
100	100	6.3	12.5	18.8	25.0	31.3	37.5
120	107	6.7	13.4	20.1	26.8	33.4	40.1
140	112	7.0	14.0	21.0	28.0	35.0	42.0
160	116	7.2	14.5	21.8	29.0	36.3	43.5
SITE INDEX 55							
60	63	3.9	7.9	11.8	15.8	19.7	23.6
80	76	4.7	9.5	14.2	19.0	23.8	28.5
100	85	5.3	10.6	15.9	21.3	26.6	31.9
120	91	5.7	11.4	17.1	22.8	28.4	34.1
140	95	5.9	11.9	17.8	23.8	29.7	35.6
160	98	6.1	12.2	18.4	24.5	30.6	36.8
SITE INDEX 45							
60	51	3.2	6.4	9.6	12.8	15.9	19.1
80	62	3.9	7.8	11.6	15.5	19.4	23.3
100	69	4.4	8.6	12.9	17.3	21.6	25.9
120	74	4.6	9.2	13.9	18.5	23.1	27.8
140	78	4.9	9.8	14.6	19.5	24.4	29.3
160	80	5.0	10.0	15.0	20.0	25.0	30.0

[1]Board feet = 2.084 (Basal area x Height). Board-foot volume by Scribner Dec. C. log rule for trees 7.6 inches DBH to a 6-inch top d.i.b. (Buckman 1962).

[2]Must be in trees 7.6 inches DBH and larger.

Table 10. — *Current annual board foot growth per acre*[1] *for even-aged red pine stands by site, age, and stand density*

Total age	Total height	Stand density - basal area per acre[2] 30	60	90	120	150	180
Years	*Feet*	*Board feet*					
SITE INDEX 75							
60	86	751	959	1112	1211	1255	1245
80	103	670	887	1039	1126	1148	1105
100	115	560	785	936	1016	1023	958
120	124	433	659	807	878	871	812
140	130	365	595	743	810	795	699
160	134	320	556	709	777	762	662
SITE INDEX 65							
60	74	556	737	856	943	999	993
80	89	467	654	766	860	878	841
100	100	339	531	661	728	732	694
120	107	242	440	571	634	630	560
140	112	153	352	482	541	530	472
160	116	127	327	454	509	491	400
SITE INDEX 55							
60	63	382	539	655	732	769	765
80	76	286	445	556	619	635	602
100	85	185	352	466	527	534	488
120	91	95	247	361	436	436	379
140	95	--	184	295	348	340	273
160	98	--	135	244	291	276	201
SITE INDEX 45							
60	51	242	365	457	516	542	537
80	62	155	284	374	425	437	410
100	69	48	182	273	320	325	300
120	74	--	102	192	236	233	183
140	78	--	29	116	155	161	103
160	80	--	--	102	142	131	71

[1]Board foot growth = 2.084 (basal area growth x height + height growth x basal area + basal area growth x height growth) (Buckman 1962).

[2]Must be in trees 7.6 inches DBH and larger.

Table 11. – *Rotation ages for maximum mean annual board foot growth*[1] *in red pine periodically thinned to a given stand density by site index*

Planted trees/A	Basal area density after periodic thinning: 30	60	90	120	150	180
Number						
SITE INDEX 75						
	Rotation age - years					
400	63	93	103	113	118	103
800	83	103	103	113	143	123
1200	83	103	113	123	--[2]	--
1600	103	113	113	143	--	--
	Board feet per acre per year					
400	331	614	831	980	1013	841
800	302	561	775	894	867	654
1200	297	542	713	813	--	--
1600	286	507	682	757	--	--
SITE INDEX 65						
	Rotation age - years					
400	93	83	103	103	123	98
800	83	103	103	133	148	118
1200	103	103	113	143	--	--
1600	103	113	118	143	--	--
	Board feet per acre per year					
400	247	471	654	774	732	618
800	237	447	605	676	583	415
1200	231	422	559	611	--	--
1600	222	402	524	558	--	--
SITE INDEX 55						
	Rotation age - years					
400	93	93	103	118	113	78
800	93	103	123	143	138	143
1200	103	103	133	--	--	--
1600	123	133	143	--	--	--
	Board feet per acre per year					
400	189	367	496	555	492	394
800	184	336	451	448	340	161
1200	172	322	411	--	--	--
1600	151	275	346	--	--	--
SITE INDEX 45						
	Rotation age - years					
400	98	108	123	118	88	88
800	103	123	128	138	--	--
1200	103	118	143	--	--	--
1600	103	133	--	--	--	--
	Board feet per acre per year					
400	124	245	336	329	263	263
800	113	217	259	226	--	--
1200	104	187	211	--	--	--
1600	97	156	--	--	--	--

Source: Unpublished red pine yield tables for managed plantations and natural stands in the Lake States. Computer program developed by A. L. Lundgren (1971), from growth and yield studies at the Northern Conifers Laboratory by R. E. Buckman and R. F. Wambach.

[1]International 1/4-inch board foot volumes in trees 9 inches d.b.h. and larger to a 6-inch top d.i.b.

[2]Mean annual growth did not culminate prior to 153 years of age in these high density stands.

Metric Conversion Factors

To convert	*to*	*Multiply by*
Acres	Hectares	0.405
Board feet[1]	Cubic meters	0.005
Board feet/acre[1]	Cubic meters/hectare	0.012
Chains	Meters	20.117
Cords[1]	Cubic meters	2.605
Cords/acre[1]	Cubic meters/hectare	6.437
Cubic feet	Cubic meters	0.028
Cubic feet/acre	Cubic meters/hectare	0.070
Degrees Fahrenheit	Degrees Celsius	[2]
Feet	Meters	0.305
Gallons	Liters	3.785
Gallons/acre	Liters/hectare	9.353
Inches	Centimeters	2.540
Miles	Kilometers	1.609
Miles/hour	Meters/second	0.447
Number/acre	Number/hectare	2.471
Ounces	Grams	28.350
Ounces/acre	Grams/hectare	70.053
Pounds	Kilograms	0.454
Pounds/acre	Kilograms/hectare	1.121
Pounds/gallon	Kilograms/liter	0.120
Square feet	Square meters	0.093
Square feet/acre	Square meters/hectare	0.230
Tons	Metric tons	0.907
Tons/acre	Metric tons/hectare	2.242

[1]The conversion of board feet and cords to cubic meters can only be approximate; the factors are based on an assumed 5.663 board feet (log scale) per cubic foot and a cord with 92 cubic feet of solid material.

[2]To convert °F to °C, use the formula 5/9 (°F-32) or $\frac{°F-32}{1.8}$.

Common and Scientific Names of Plants and Animals

Common name	*Scientific name*
Plants	
Aspen, bigtooth	*Populus grandidentata*
quaking	*Populus tremuloides*
Birch, paper	*Betula papyrifera*
Blackberries	*Rubus occidentalis*
Blueberries	*Vaccinium spp.*
Fir, balsam	*Abies balsamea*
Hazel	*Corylus spp.*
Juneberries	*Amelanchier spp.*
Maple, red	*Acer rubrum*
sugar	*Acer saccharum*
Oak, bur (scrub)	*Quercus macrocarpa*
no. pin	*Quercus ellipsoidalis*
no. red	*Quercus rubra*
Pine, jack	*Pinus banksiana*
red	*Pinus resinosa*
white	*Pinus strobus*
Prickley ash	*Xanthoxylum americanum*
Raspberries	*Rubus strigosus*
Red pine shoot blight	*Sirococus strobilinus*
Root rot	*Fomes annosus*
Roses	*Rosa spp.*
Scleroderris	*Scleroderris lagerbergi*
Spruce, black	*Picea mariana*
white	*Picea glauca*
Sweetfern	*Comptonia peregrina*
Animals	
American bald eagle	*Haliaeetus leucocephalus*
Bark beetle	*Ips pini*
Deer	*Odocoileus virginianus*
European pine shoot moth	*Rhyacionia buoliana*
Hare	*Lepus americanus*
Jackpine budworm	*Choristoneura pinus*
Mice	*Microtus pennsylvanicus*
Pine root collar weevil	*Hylobius radicis*
Pine tussock moth	*Olene plagiata*
Pine webworm	*Tetralopha robustella*
Porcupine	*Erethizon dorsatum*
Saratoga spittlebug	*Aphrophora saratogensis*
Sawflies	*Neodiprion spp.*
White grubs	*Phyllophaga spp.*
White pine weevil	*Pissodes strob.*
Zimmerman pine moth	*Dioryctria zimmermani*

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key – out of the reach of children and animals – and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

Note: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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Benzie, John W. 1977. Manager's handbook for red pine in the north-central States. USDA For. Serv. Gen. Tech. Rep. NC-33, 22 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Provides a key for the resource manager to use in choosing silvicultural practices for the management of red pine. Control of stand composition and growth, regulating the forest, and control of stand establishment for timber production, water, wildlife, and recreation are discussed.

OXFORD: 174.7 *Pinus resinosa:* 187(77):61:2.
KEY WORDS: *Pinus resinosa*, Lake States, silviculture, timber management.

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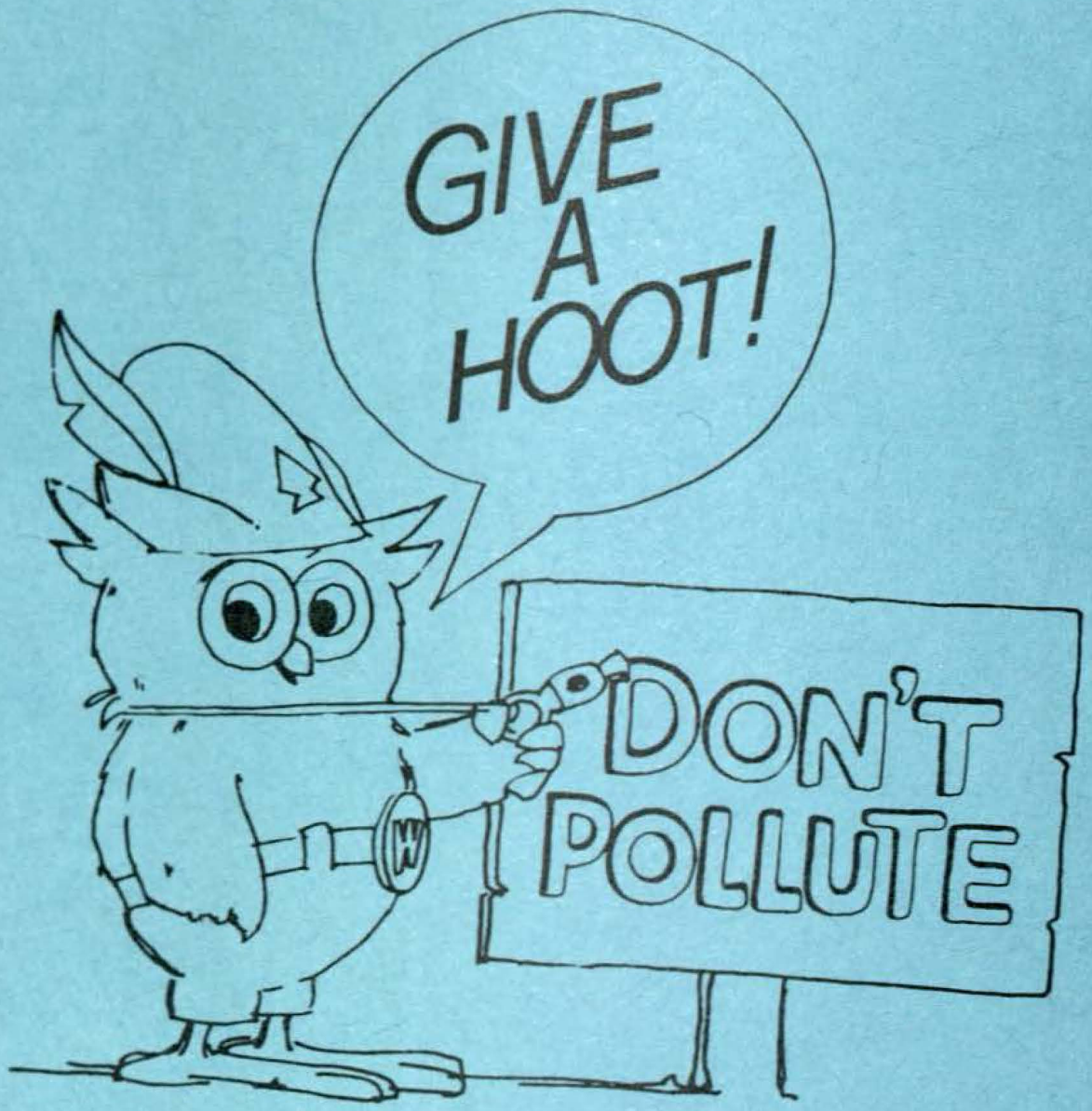

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